California Regional PM_{10} and $PM_{2.5}$ Air Quality Study (CRPAQS)

Statement Of Work – CRPAQS Data Analysis Task 1.3
EVALUATION OF SURFACE AND ALOFT
METEOROLOGICAL MEASUREMENT METHODS

STI-902324-2291-WP
Sonoma Technology, Inc.

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Introduction

Task 1.3 focuses on evaluating the adequacy and validity of meteorological measurements to resolve the spatial and temporal atmospheric features of interest in the overall data analysis effort. Knowing the horizontal and vertical representativeness of the measurements will enable other researchers to make better use of the meteorological data.

Numerous surface and upper-air instruments were deployed during the summertime and wintertime field studies and *appear* to provide good coverage of the atmospheric phenomena such as eddies, low-level jets, upslope/downslope flows, etc., often observed in the San Joaquin Valley (SJV). However, because some of the meteorological measurements were made at sites within complex terrain to characterize local or regional flows, the representativeness of these measurements may not extend far from the monitoring sites. To evaluate whether the meteorological network resolved atmospheric phenomena, we will perform two major tasks: (1) define the spatial and temporal scales of the phenomena, which can vary by research objective as well as by season, and (2) determine the spatial representativeness of the surface and aloft meteorological measurements by using the surrounding terrain.

The intent of Task 1.3 is to qualitatively evaluate the spatial (horizontal and vertical) representativeness of the meteorological data and generate maps of the SJV showing the representativeness at each site by altitude and by time of day. To accomplish this task, we propose to understand the different types of vertical flow regimes by computing and examining transport statistics using surface and aloft data. Transport statistics provide daily averaged wind runs, scalar winds, and recirculation factors and were used with IMS-95 data to identify aloft layers influenced by terrain and/or synoptic-scale forcing. Since these flows are strongly affected by the surrounding terrain, we propose to use Geographic Information System (GIS) tools to estimate zones of horizontal representativeness around each measurement site. GIS will help us determine the underlying changes in the terrain surrounding the site that affect representativeness. We will explore several different ways to use terrain to estimate the horizontal extent of representativeness from the measurement site.

As an end product, meteorological representativeness maps will be overlaid with the chemistry sites to locate nearby meteorological sites with similar conditions. In addition, by overlaying the spatial extent of a meteorological feature (eddy, jet, fog layer, etc.), one can further determine if sufficient measurements exist to resolve that atmospheric feature. These maps and site overlays will be made available on a web page for other group analyses.

Scope of Work

Background

To some extent, adequacy of the upper-air measurements has been addressed by Dye et al. (1998) in California's central valley. During IMS-95 data analysis, computed transport statistics were used to investigate the adequacy of surface and aloft meteorological wind measurements for characterizing transport conditions (periods when good ventilation, stagnation, or potential recirculations may have occurred). The results showed extremely complex flows with aloft layering that was produced by a combination of locally and regionally induced terrain effects, synoptic-scale forcing, and thermally stable conditions found in the valley during the winter. **Figure 1** shows an example of the transport statistics computed for the Fresno radar wind profiler site on January 6, 1996, illustrating several different flow regimes. **Figure 2** shows averaged wind profiles for a 14-day period at the mouth of the King's River Canyon site. It should be noted that three distinct wind regimes exist: terrain-forced flows near the ground that are caused by drainage winds from the King's River Canyon, regionally forced flows between 300 and 800–1400 m that are altered by terrain, and aloft wind regimes influenced by synoptic-scale forces.

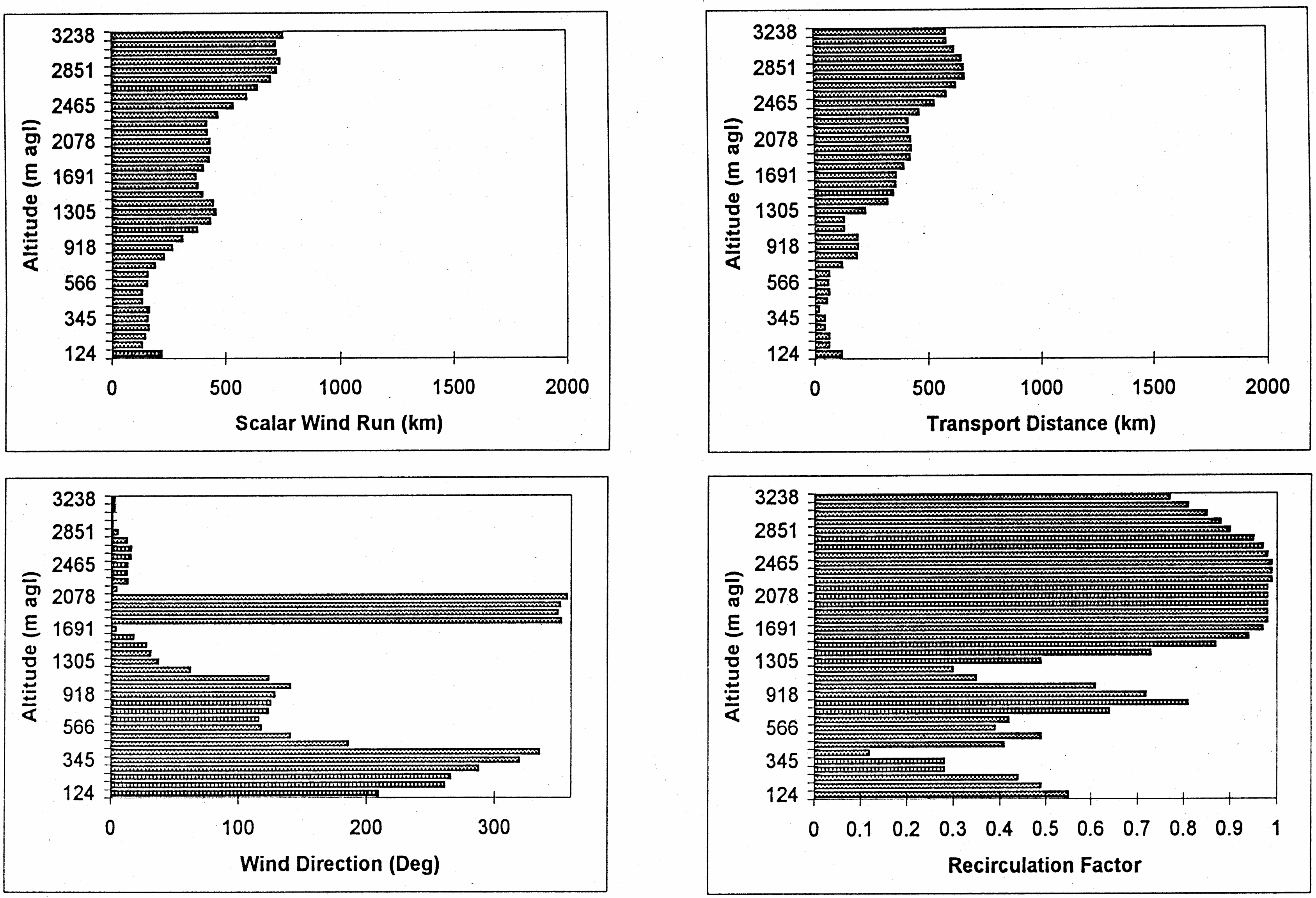

Figure 1. Transport statistics for a 24-hr period at the Fresno radar wind profiler site on January 6, 1996, showing scalar wind run, transport distance, average wind direction, and recirculation factor (Dye et al., 1998).

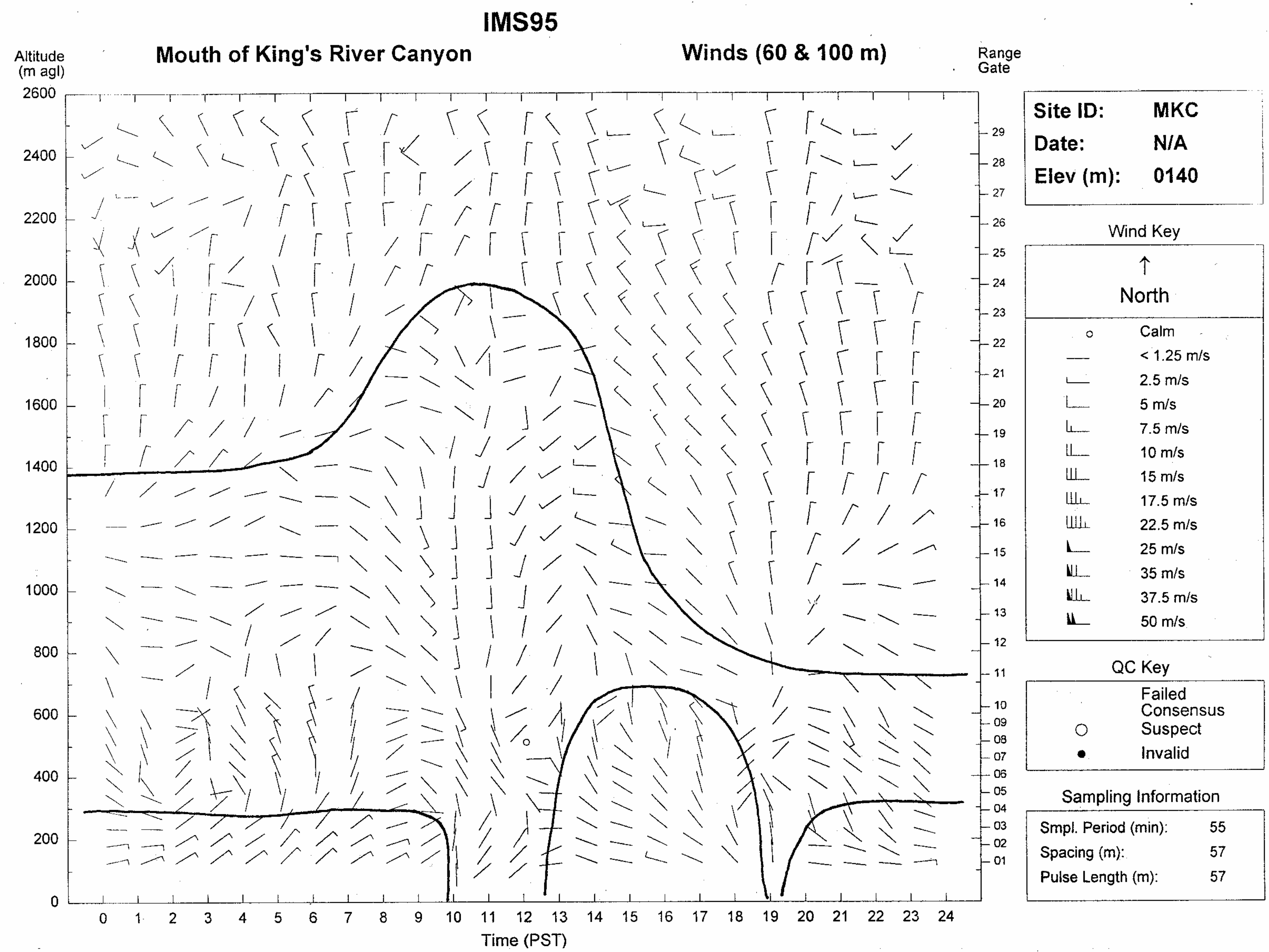

Figure 2. Averaged winds for the 14-day period (December 9-10 and December 23-28, 1995, and January 1-6, 1996) for the radar profiler at the mouth of the Kings River Canyon (Dye et al., 1998).

Methods

The methods used for this project will be to compute transport statistics from the upper-air and surface meteorological data and to use ArcInfo's Spatial Analyst Software Package and 30-m terrain files to provide estimates of representativeness.

To evaluate periods of ventilation, stagnation, or potential recirculation, integral statistics will be computed using the continuous upper-air (i.e., radar profiler and sodar) and surface meteorological data based on work by Allwine and Whiteman (1992). The transport quantities are numerically described in Equations 1 through 4 and represent the scalar wind run S (km), the resultant (vector) transport distance L (km), the resultant (vector averaged) wind direction θ (degrees from true north), and the recirculation factor R.

$$S = \int_{t}^{t+t} \left| V(t) \right| dt \qquad \textbf{(1)}$$

$$L = \sqrt{x^2 + y^2} \qquad \textbf{(2)}$$

$$q = \tan^{-1}\left(\frac{x}{y}\right) \qquad \textbf{(3)}$$

$$R = \frac{L}{S} \qquad \textbf{(4)}$$

where:

$$x = \int_{t}^{t+t} u(t)dt$$

$$y = \int_{t}^{t+t} v(t)dt$$

u = east-west component of the wind
v = north-south component of the wind

The recirculation factor is a ratio of the resultant transport distance to the scalar transport distance (wind run). When R is equal to 1, steady transport has occurred during the integration period. Values of R close to 1 typically characterize good ventilation conditions and periods of potentially long-range transport. Conversely, low values of R represent periods of stagnation or recirculation. Stagnation is indicated by shorter scalar wind runs (i.e., low wind speeds) and recirculation is characterized by low values of the vector transport distance compared to the scalar wind run. For example, if R is 0.25 and the vector-averaged wind run is 50 km, then the scalar wind run would be 200 km. Over a 24-hr period, this would not be characteristic of stagnant conditions. For such conditions to occur, air must have circulated back and forth through the area of interest.

ArcInfo's Spatial Analyst software (ESRI, 2001) will be used with digital elevation data to aid in estimating regions of representativeness around each monitoring site. Spatial Analyst contains analysis tools that allow users to identify and investigate spatial, quantitative, and statistical relationships among geographic features and variables.

Analysis Approach

The following analysis approach will be used to examine the spatial representativeness of the meteorological data. Each task element is listed below:

1. Acquire meteorological data. Download the surface and upper-air data from the CRPAQS database for one major episode during each of the summer and winter sampling periods. Acquire all upper-air data including the radar wind profiler, RASS, sodar, and rawinsonde data. These data will be examined for problems, but we assume that all the data has received Level 1A data validation. Level 1A data validation includes data that have been subjected to quantitative and qualitative reviews for accuracy, completeness, and internal consistency. Staff who understand the measurement systems and the meteorological processes expected to be contained in the data performed the qualitative reviews. Data will be converted into an internal format suitable for GIS analysis and processing with STI's profiler processing software.

2. Process meteorological data. Determine data availability and compute transport statistics using the surface and upper-air meteorological measurements.

    - Compute a data availability matrix for each measurement site that summarizes the temporal resolution, station altitude, lowest and highest measurement heights, and any significant data gaps during the episodes.

    - Calculate transport statistics to identify periods and altitudes of ventilation, stagnation, or recirculation using the upper-air (i.e., radar profiler and sodar) and surface meteorological data. For each site, identify layers where the local, regional, and synoptic-scale forcing occurs, which will be a function of the site's proximity to terrain. These layers will be different for the summer and winter episodes.

    - Create averaged diurnal wind profiles for each site and each episode (see Figure 2). These time-height cross-sections of winds can be extremely useful for identifying the heights where local, regional, and synoptic-scale forcing occurs.

3. Develop representativeness criteria. Use the height of these layers to develop criteria for estimating the spatial representativeness of the surface and aloft measurements.

    - In the locally forced layer nearest the ground, the spatial representativess likely does not extend over a wide area. In addition, the extent is most likely limited by the surrounding terrain and its slope. The GIS tools will be used to estimate the horizontal extent of this low-level layer by using the height of the measurement and the slope and altitude of the surrounding terrain, in effect creating a zone of representativeness around each site.

- In the regionally forced layer, the representativeness of the aloft meteorological variables probably extends over a wider region but is still influenced by terrain. We will use the layer heights combined with the height of the terrain using GIS to help bound the representativenss of meteorological conditions at each site.
- In the synoptically forced layer, we will use an analysis technique such as correlation, guided by manual reviews by a meteorologist to establish the representativeness at this altitude.
- In developing these criteria, we will use our understanding of upper-air data and atmospheric processes to aid us in determining the representativeness of the criteria to use with GIS.

4. Analysis of representativeness using GIS. Base maps of input data sets will be prepared, including digital elevation and locations of surface and upper-air meteorological data collection sites. New data will be derived from the input data sets such as the slope of the terrain and/or elevation contours. Distance calculations will be performed to derive spatial extents (representativeness polygons) by considering topographical influences for different heights above ground.
    - For example, if a measurement site was located in the SJV but near the mouth of a river canyon, depending on the altitude and time of day, aloft measurements would be influenced by terrain-forced flows. Starting at the lowest level, we might find from the analyses in task element 3 that, on average, the downslope flows affect the winds from the surface to about 400 m agl. This locally forced flow is probably not very representative of a large area; rather, it depends on the terrain characteristics. We would then use GIS with digital elevation data to estimate the spatial extent of the measurements based on change in terrain height, terrain slope, etc. At this level the meteorological conditions from this measurement site are likely to represent a limited distance up the river canyon and a greater distance out into the SJV. We will then create a zone of representativeness around the site. This process would be repeated from the next highest level.
5. Interpretation of results. Evaluate representativeness maps to ensure that the results are physically consistent with atmospheric processes and our understanding of the flows in the SJV. In addition, we will overlay the chemistry sites on the meteorological representativeness maps to determine sites where the meteorology and chemistry data are coupled; these data can be used during other analyses listed in the RFP. Next, we will determine the spatial extent of several atmospheric phenomena (eddy, low-level jet, fog, etc.) and whether enough measurements exist to represent the given phenomena.
6. Validation of results. Verify the generally applicable conclusions of this analysis by comparing representativeness at selected sites to the consistency of the wind fields computed in Task 5.2.
7. Documentation. Document the approach and results of this exploratory analysis for journal publication. In addition, we will create a web page that allows other researchers to view the representativeness maps and overlay the meteorological and/or chemical site locations.

Time Line

Figure 3 illustrates the anticipated timeline for the Task 1.3 analyses. We will have acquired the data by February 2003 and performed the representativeness analysis by June 2003. Our initial findings will be available by early July 2003. We anticipate completing work by the end of August 2003.

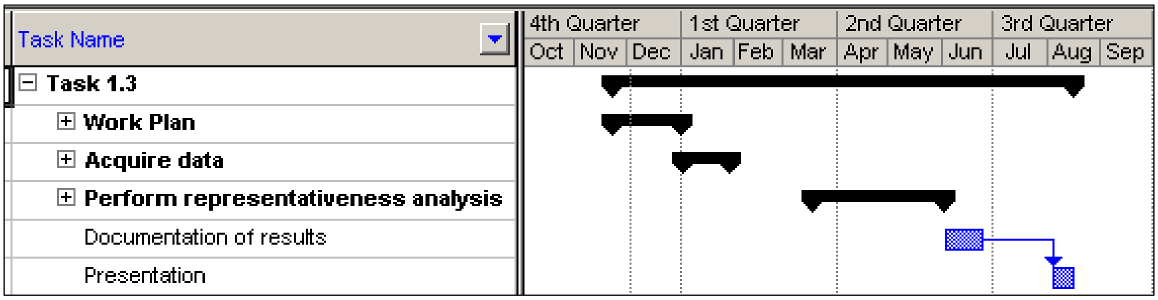

Figure 3. Timeline for Task 1.3.

Schedule of Deliverables

Table 1 lists the deliverables to be prepared under Task 1.3.

Table 1. Schedule of deliverables.

Deliverable	Deliverable Due Date
Draft final summary	July 1, 2003
Content for ARB web page	September 1, 2003
Revised final summary	October 1, 2003
Publication	Fall 2003

Description of Deliverable(s)

The deliverables for this task will be maps for ARB's web page showing representativeness with overlays of the meteorological and chemical monitoring sites, and a final summary including

- transport statistics like those shown in Figures 1 and 2;
- table summarizing the data availability of the surface and upper-air measurements during the episodes; and
- final summary detailing the approach and results of this analysis for journal publication, with appendices containing the transport statistics.

ARB Staff Assigned to This Task

The ARB Project Manager assigned to this Task is

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STI Staff Assigned to This Task

The STI Project Manager is Lyle R. Chinkin. The STI Task Managers assigned to this task are Timothy S. Dye (Principal Investigator) and Charley A. Knoderer (Task Manager).

Percentage of Work, Data Products To Be Performed/Delivered by ARB

Assuming all meteorological data has been validated to Level 1A with documented quality control codes, units, site identifiers, site locations, etc., ARB will not be required to perform any work for Task 1.3. Level 1A data validation includes data that have been subjected to quantitative and qualitative reviews for accuracy, completeness, and internal consistency. Staff who understand the measurement systems and the meteorological processes expected to be contained in the data performed the qualitative reviews. Problems with data quality may limit the types and extent of data analysis.

Software and Models To Be Used by STI

We will use Arcinfo's Spatial Analyst software (ESRI, 2001), GraphXM, Microsoft Excel spreadsheets, Microsoft Access databases, and FORTRAN programs to perform the described analyses. STI has all of these products.

Models, Reports, or Other Data To Be Supplied to STI by ARB

STI will acquire the surface and upper-air meteorological data from the CRPAQS database. We assume that meteorological data will be validated to Level 1A with documented quality control codes, units, site identifiers, site locations, etc. Given the budget constraints, obtaining meteorological data from sources other than the CRPAQS database is beyond the scope of this project.

References

Allwine K.J. and Whiteman C.D. (1992) Single-station integral measures of atmospheric stagnation, ventilation and recirculation. In *Preprints: American Meteorological Society 6th Conference on Mountain Meteorology,* American Meteorological Society, Boston, MA.

Dye T.S., Kwiatkowski J.J., MacDonald C.P., Ray S.E., Chinkin L.R., and Lindsey C.G. (1998) Measurement methods validation: adequacy and validation of meteorological measurements aloft during IMS-95. Final report prepared for the California Air Resources Board, Sacramento, CA by Sonoma Technology, Inc., Petaluma, CA, STI-997218-1766-FR, July

ESRI (2001) ArcGIS Spatial Analyst <http://www.esri.com/software/arcgis/arcgisxtensions/spatialanalyst>. Last accessed December 10, 2001.